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THE GEOLOGY OF MICHIPICOTEN ISLAND

BY

E. M. BURWASH, M.A.

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THE GEOLOGY OF MICHIPICOTEN ISLAND

I. INTRODUCTORY.

Michipicoten Island lies in the north-eastern part of Lake Superior, about ten miles distant from the northern shore, which here for some distance runs a little north of west, curving northward toward the west. The island is roughly elliptical in shape, about sixteen and five-eighths miles long by six miles in greatest width; its longer axis lies nearly east and west or roughly parallel to the coast, and its western end is situated south and a little west of the mouth of the Pukaswa river. It forms one of the largest developments in Canadian territory of the Keeweenawan series of rocks, so extensively exposed and studied by American geologists on the western and southern shores of the lake. Owing to the fact that the copper deposits on the island have not up to the present proved important, its geology has not received at all the same measure of attention that has been bestowed upon the formation elsewhere, and a *résumé* of the literature of the subject may be briefly made.

1. Sir William Logan in the *Geology of Canada, 1863*, reports upon the island as follows :—

"The strata of which it is composed have a general dip to the east of south, and the inclination appears seldom to fall short of thirty degrees. The lower strata, toward the north side of the island, particularly as indicated at the upper end, appear to be composed chiefly of amygdaloidal trap, with occasional beds of trap-conglomerates, red sandstones, and shales; while toward the south these are overlaid by a considerable amount of compact earthy or sub-resinous red trap, assuming sometimes an obscure and sometimes a distinct porphyritic character, by the display of ill-defined crystals of red felspar or well-marked crystals of transparent colourless quartz.

"Along nearly the whole of the south side of the island, the trap assumes a more resinous aspect, and its colour becoming black, it presents the characters of pitchstone and

pitchstone porphyry. Some of the beds associated with these are of an amygdaloidal character and exhibit large agate-veins, which run chiefly in the direction of the strike, but frequently also transverse to it.

"About three-fourths of a mile out in front of the harbour, which is half-way down the south side, a few narrow islands occur, presenting beds of a peculiar character, amounting to between sixty and seventy feet, dipping southward at an angle of twenty degrees. They are of a general red colour, spotted and patched with yellowish white, and wherever a crack exists the rock is blanched to a small distance on each side of it. The surfaces are uneven, and peculiarly marked with festooned and finely-wrinkled forms, composed of very thin close-fitting laminae, with a ligneous aspect, having a thickness sometimes exceeding one or two inches. The rock scarcely resembles a trap, nor does it bear the character of indurated shale; but it may perhaps be an indurated mixture of volcanic mud and ashes, in which the wrinkles result from a partial flow. The total volume of the formation developed in Michipicoten Island, at the most moderate dip observed, would not fall short of 12,000 feet."

2. Thomas Macfarlane, of the Geological Survey of Canada, visited the island in 1865 and reported upon it in his *Report on Lake Superior*.[1] His description of the rocks upon the island occupies several pages, but has been largely rendered obsolete by later methods of petrographic study. His description is chiefly of value for its numerous records of dip and strike, establishing the general trend of the formation and the flattening of the dip toward the southern part of the island.

3. Professor R. D. Irving, in his *Copper-bearing Rocks of Lake Superior*[2] gives the results of a microscopic examination of nineteen rock specimens collected on Michipicoten island by Mr. Macfarlane, comparing them with rocks of the

[1] Geol. Surv. of Canada, Report of Progress from 1863 to 1866, pp. 113 et seq.

[2] U. S. Geol. Surv., Monog. V, 1883.

Keeweenawan formation on the south and west shores. More detailed reference to his descriptions of these rocks will be made in connection with the study of them in this paper. Not having visited the island, he accepts the stratigraphical account of it given by Logan and Macfarlane. His report establishes the connection of the Michipicoten with the other copper-bearing rocks of the Lake Superior basin, fixing it as a projecting part of the northern edge of the great synclinal trough which underlies nearly the whole of the waters of the lake. The nearest exposures of similar rocks, he states, are at the Battle islands about 100 miles in a straight line to the north-west and at a point on the east shore of the lake about two miles north of Cape Choyye, which lies some 18½ miles south of the mouth of the Michipicoten river, and about 33 miles east of the eastern end of the island.

4. The Report of the Royal Commission on the Mineral Resources of Ontario (1890) refers to the general structure of the island and its resources in copper and agate (p. 38). Evidence as to the nature of the copper deposits and the extent of the mining operations carried out upon them was given by Messrs. Joseph Cozens, J. S. Williams, and E. P. Borron. From the evidence of the first mentioned gentleman it appears that copper occurs in two distinct classes of deposits on the Charles Jones location, a conglomerate vein some eight feet in width and an amygdaloid, upon which the principal work was done, both deposits being parallel with the general strike and consisting of impregnated beds, as at the principal deposits of Keeweenaw point, and not of veins transverse to the formation. Mr. Williams described the deposit on the Bonner location as consisting of quartz, calcite, epidote, iron pyrites, and native copper, and running about east and west, or parallel with the general strike at that part of the island (the north shore). Mr. Cozens also reports the discovery of native silver on this location (pp. 60 and 103).

5. During the summer of 1898 Professor A. P. Coleman, acting for the Bureau of Mines of Ontario, visited the island, and made a cursory examination of its principal features.

In his report (Bureau of Mines of Ontario, 1899) he describes the raised beaches which occur on the island in common with the rest of the Lake Superior shores, and says :—

"A very interesting group of beaches is to be found in the western end of Michipicoten island, both on the north and on the south sides, easily examined on the road leading over the hills from the Quebec mine to Quebec Harbour. There are several fairly distinct sets of gravel beaches, each having a number of ridges below the highest one. The lowest one is from 15 to 22 feet above the water and is marked by a fine sea-cave whose floor is at the lower level. Next come indistinct beach-lines running up to 65 feet above the lake, where a terrace affords space for several houses. Above this there are faint stages culminating at 78 feet, and then apparently a gap until 128 feet, when fairly distinct wave lines begin and run up to 178 feet. At 204 feet there is a well-marked gravel beach, perhaps just the highest stage of the last series; and at this level on the south side of the divide a lake is found, probably dammed by a beach-deposit. Above this there is a wide terrace occupied by a farm, its highest point being 233 feet. There is a lake at this level also. The highest terrace observed reaches 295 feet. The terrace lying somewhat above the 400-foot level, found at so many points to the east and south-east, was not observed, but may yet be found among the higher hills of the island which were not explored. A comparison of the series of beaches just given and those of Dog river, 35 miles to the north-east as measured by Lawson, shows comparatively few points of agreement, the only exact one being the level of the lowest beach in each, 15 and 16½ feet respectively. Whether there has been differential elevation, placing the beaches at Dog river higher than the corresponding beaches at Michipicoten island is hard to determine, particularly when one recalls that almost all these beaches are composite and have a range of a number of feet."

Dr. Coleman also described somewhat in detail the quartz porphyry at the eastern end of the island. His report also

...tions the occurrence of Keeweenawan rocks on the north ...ore between Pilot Harbour and Pukaswa, not noted by Irving, which seems to indicate that the entire channel be...ween the island and mainland is underlain by these rocks, ...nd accounts for the conglomerate, with Keeweenawan peb...les, which forms one of the lowest members of the series on ...e island. This point will require attention at a later part ...f the paper.

The writer's sincere thanks for encouragement and assi... ...e due to Professors T. L. Walker and A. P. Coleman, ...f the University of Toronto, to the Honourable Charles D. Walcott, Director of the United States Geological Survey, to Mr. G. F. Matthew, of St. John, New Brunswick, to Mr. ...seph Cox..., D.L.S., of Sault Ste. Marie, and to Dr. A. G. Wilson, of McGill University, Montreal.

II. GENERAL CONSIDERATIONS AND PLAN OF WORK

The island, as already described by earlier explorers, consists of a series of well-defined eruptive beds, with some interstratified sedimentaries. The general strike is a little north of east, or parallel to the longer axis of the oval, and the beds all dip to the southward at angles which range from ... on the north-western side to about 14° on some islands off the southern shore. By far the greater part of the thickness of the deposits consists of eruptive flows, most of them several hundred feet in thickness, as compared with the sedimentaries which occupy a thickness in most cases of from one to ten feet, except at the west and north-west parts of the island, where conglomerates of considerable thickness occur. The ...ous beds, with one important exception, (that occupying ... north shore of Channel lake) are continuous from shore ... shore across the island. They seem to attain their greatest ...ickness in the centre and eastern parts of the island, tapering ...ay to an inconsiderable thickness at the western end, so ...t nearly all are crossed by the road which runs from Quebec ...arbour to the Quebec mine and appear at the west end of ...e island, while their eastern or north-eastern extremities

are found distributed all along the greater part of the eastern and northern coasts, although the strikes at the east end show also a distinct but less marked convergence. To this fan like arrangement in part is due the apparent confusion found by Macfarlane in endeavouring to trace the series along the eastern shore. The sedimentary rocks, on the other hand, are not continuous across the island, so far as observed, but are largely developed only at the western end, where the igneous flows thin out giving the impression at first sight that the conglomerates found here were deposited upon the flanks of the extruded masses. The igneous beds at this part of the island have also a less perfectly porphyritic and more felsitic texture, a laminated structure due to flow or pressure, and also a steeper dip than at the east end. The igneous flows have in general a tendency to jointing in a direction curving, along the south shore of the island where it is most easily observed, from 315° to 325°, or roughly perpendicular to the general [illegible].

These facts, taken in connection with the former higher levels of the lake and wave action at those levels, explain nearly all the topographical features of the island. Here, as throughout the Keeweenawan formation,[1] the gently dipping eruptive beds present ridges, or cuestas, sloping gradually on the dip side and breaking off sharply in cliffs or steep slopes of talus upon the opposite, in this case the northern, side. The intervening valleys of erosion[2] were no doubt largely produced by the waters of the lake at higher levels, a process which may be seen in operation at the present time along the southern shore of the island. The inland cliffs were then shore cliffs of straits or bays of the lake, like those on the northern side of Hope, Long, and Stack islands. On the second of these islands a crack several feet in width extends parallel to the cliff and about twenty yards distant from it, showing the undermining action of the strait, not [illegible] wide, which separates the [illegible] from the

in island.[1] The removal by the waters of the lake of a [illegible] (acidic) bed, through an opening broken in a more resistant basic one, is well illustrated by Quebec and Cozen's Harbours, both of which are hollowed out of the same flow, reddish brown quartzless porphyry, and protected by a barrier of black rock which resembles the "ashbed diabases" of Keeweenaw Point, and has in parts the properties of a pitchstone porphyry.

The basic rocks (diabases) are the most resistant to erosive forces, especially the compact or vitreous kinds, and these invariably form ridges of considerable height, running with the strike: the highest point on the island, that used by the American Hydrographic Survey for its station, stands 937 feet above the lake and is composed of a dark grey pitchstone porphyrite. The quartz porphyrites attain a considerable height as ridges only at the east end of the island, where their quartz phenocrysts are most fully developed. In the centre they are often eroded down to a level, as at Quebec Harbour and underlie somewhat extensive swamps, or lakes of rounded outline, the remains of ancient bays similar in character to Quebec Harbour. These flats are intersected with hills somewhat irregularly arranged, the remnants of once continuous ridges. The same result is obtained at the lake on the road about two miles south of the Quebec mine, where a number of softer basic beds of steep dip, together with a large porphyry dyke, are worn down to a flat surface, at the level of an ancient beach whose sand covers thinly their upturned edges. Examples of beds worn down to the level of the water in this way are reported from the Keeweenawan deposits on the western shore of Lake Superior. Even the most resistant ridges are traversed by valleys, like the Saw-tooth Mountains of the Minnesota coast described by Irving, giving a characteristic serrated appearance, which is well seen from the deck of a steamer passing along the south-eastern shore

of the island. These valleys seem to correspond to the lines of jointing already mentioned as being constant in direction, and not being exactly perpendicular to the strike give the successive hills of the same bed an appearance of being set *en échelon*, or with corners toward each other, rather than in line abreast.

The general plan of exploration determined upon before visiting the island involved an examination of its coast line, where the best exposures are to be had, and the making of as many sections from north to south across the island as possible. For this purpose it was thought that some of the surveys run about 1881 might still be available, but as this proved to be impossible, on inquiry after reaching the island, owing to the density of the undergrowth in most parts of it, the plan had to be modified. The road from Quebec Harbour to Quebec mine gives one very good section remaining, as it does across nearly all the principal beds. The lake north of Quebec Harbour, known as Channel lake, is connected by an old road with the harbour and by trail with Birch and Coldwater lakes to its west and north. There is also a trail running about a mile from a point on its north shore, nearly opposite to where the road reaches it, along a trout stream which enters through a valley cutting the cuesta on the north side of Channel lake, and another trail extends from near its east end northward along the east boundary of the Bonner location to a point near the northern side of the island. Apart from these routes, the only possible method of sectioning would be by compass lines through the woods, or possibly with a canoe, and portaging from lake to lake. It was found, however, that the time available for the examination of the island, about three weeks, was fully occupied in the examination of the rocks along the more accessible routes above mentioned.

A micrometer survey was made of the road from Quebec Harbour to the mine, plotting the geology, and keeping a record of the principal heights by barometer. As the islands off the south shore are a somewhat important feature in the geology of the whole and are insufficiently indicated on the

Crown Lands Department map which was used as the basis of the work, a day was spent in making a survey of them also. The old road to Channel lake, now so grown up as to leave only a path, was surveyed, the shores of the lake examined from the decks of a boat kept there by the lighthouse-keeper, to whom we were also indebted for information as to trails, and the trails radiating from this lake to the northward were examined, and mapped by pacing with the compass. In this way the shores of Birch and Coldwater lakes were visited, but the day set apart for the exploration of the long trail northward from the east end of Channel lake unfortunately proved so stormy as to prevent our reaching the point where it begins in the small and unsafe boat available for the purpose. The exploration of the coast was finally undertaken, and, with some special attention paid to the neighbourhood of the mines at the north-west shore, occupied the rest of the time. It is very much to be regretted that at least one compass line could not have been made across the eastern part of the island, whose topographical, as well as geological, details thus remain unknown except as we were able to study them from the shore or infer them from facts observed on the western part.

The map submitted with this paper, is, as already noted, a copy of that in possession of the Surveys Branch of the Crown Lands Department of Ontario, to which has been added the topographical features given by Joseph Cozens, O.L.S., on the plan of his survey of the lots between the Bonner and Charles Jones locations. Upon this have been plotted the surveys made by the writer, including the islands off the south shore, the road from the harbour to the mine, with the lakes along its course, various trails, the more prominent topographical features noted, the different rock areas and a number of dips and strikes.

In plotting the geology of the isand, the lines of contact have been drawn between the points where they were fixed in general as directly as possible, having regard to known strikes of the beds themselves or of parallel beds. These lines have, however, been varied a little in accordance with the topo-

graphical features. In almost every case, throughout the island, the northern side of an important hill marks the northern boundary of a flow, and where the lines upon their estimated curves ran at all near to such hills they were altered if necessary to include them. Indentations in the boundaries have also been made at the crossings of streams or lakes, as in every valley the northern edges of the flows, all of which dip southward, necessarily recede to the south.

The field work, as carried out, gives three complete sections and one partial section, across the island. Commencing at Quebec Harbour and following the coast in either direction, we pass over all the beds exposed, completing both sections at the Quebec mine, where the lowest beds occur. The road from the harbour to the mine gives a third, and the route connecting the harbour with Coldwater lake part of a fourth, including an important bed not found in the other sections. Of these sections, that along the road and that around the east end of the island are the most complete. The western end of the island, which is the one especially described by Macfarlane, has some very important gaps owing to the fact that a group of softer beds, here very thin, which reach the shore in a small bay toward the north-west angle, are covered by gravel beaches. These beds, however, are well exposed along the northern and north-western shore, where they occupy considerable space. A repetition occurs in the eastern section on the north-eastern shore, where the strikes bend toward the south. A quartz porphyry flow, which runs into the lake along the southward curving shore on location Y41, reappears again for a short distance to the south-east on Y42, so that this bed and the diabase just above it in the series are encountered twice in succession in following the shore. The very striking flow of diabase-porphyrite seen along the north shore of Channel lake is not met with either on the road or at either end of the island, and therefore runs out at conjectural distances east and west of the points where it was observed. The rocks described by Macfarlane as forming a succession along the south shore from Quebec Harbour east

appear to be for the most part merely variations in texture of the same flow, which includes vitreous, felsitic and porphyritic parts, and it has been marked as continuous upon the map. For convenience of reference the different beds have been numbered in order from the top downward, no. 1 being the felsite forming the islands off the south shore.

In order to give as clear as possible an account of the conditions on the ground as traversed and also to consider each important bed as a whole, the next division of the paper will deal with each of the sections already mentioned separately, and in the petrographical division each bed will be considered separately throughout its length.

II. DETAIL OF FIELD WORK AND STRATIGRAPHICAL RELATIONS OF ROCKS

1) *Section exposed on islands off the south shore, shores Quebec Harbour, and routes north to Birch and Coldwater lakes.*

The islands off the south shore form the highest member of the series exposed and represent a partly submerged cuesta separated from the nearest shore by a strait about 4400 feet in width. The whole distance from the shore to the outside of these islands, at the lowest dip observed (12°), would represent about 960 feet in thickness of deposits, and it is probable that the thickness does not much, if at all, exceed 1,000 feet. The chain of islands begins a little to the east of the mouth of Quebec Harbour and extends about five miles and a half in a direction south of west. A slight break in the continuity of the line of islands seems to indicate that the two eastern islands represent the upper portion of the flow. The eastern islands are also the highest of the group, which is due no doubt to greater erosion having taken place at the western end of the chain.

The easternmost, or Hope island, has a general east and west bearing. The rock here, described by Logan, consists of laminae from a quarter to a third of an inch in thickness, having a general strike parallel with that of the island and

the bed, though showing many undulations, bearings taken at various points varying from 270° to 290°. The dip of these laminæ is still more variable, and appears to be in most cases steeper than the dip of the flow. It is in some cases even in the opposite direction, the readings varying from 30° S. to 70° N. In accordance with its structure this island slopes considerably more rapidly on the north than on the south side, and this applies to the slopes under water as well as above.

Long island, the next in the series, is the largest, having a length of about 6,500 feet on a bearing of about 261°, with a maximum width of 900 feet. It affords the best example of the cuesta structure, having a cliff along its north shore 150 feet in height at its highest point, and a gradual ascent on the southern side. Its southern side and its ends are in the form of a terrace, having a general height of about 15 or 20 feet above the water. (See Fig. 2.) This area was no doubt worn down to the water-level when the lake stood at the level represented by the first of the series of beaches found on the island and by the old sea-cave at the Quebec mine. Its surface is not by any means flat but presents a series of hummocks of approximately equal height formed by the enlargement of the joints in the rock, which are now represented by open trenches reaching down in many cases to the present water-level. This low area extends across both Hope and Long islands at about their centres, so that each was formerly divided into two islands. This gives a general suggestion as to the manner of division of the cuesta ridges into separate hills. In accordance with this correspondence may be looked for between the levels of old beaches observed on the island and elsewhere on Lake Superior and the heights of the passes between the summits of the cuestas throughout the island, a correspondence which was in fact observed in all the cases examined. It is also in accordance with this that in most, if not all cases, such passes do not slope up to a summit and fall immediately away again, but continue for some time level at their highest point, being in

[illegible] part of the terrace to the level of which they correspond. The sketch of Long island from the east affords a good illustration of this arrangement. A channel carved in this way, beginning originally with the enlargement of a joint in rocks projecting a little above the water, might be continued downward through a number of lower levels, or might be left dry at any one of them by the receding waters, dependent partly upon the persistence downward of the joint and partly by the dimensions attained by the channel at its first stage. The question as to the possible depth to which such a channel could be excavated below the water-level by wave action is also of importance in this connection. Suggestions are afforded by the depth of water in the channel south of Hope island, which is charted at 20 fathoms, and that toward the south side of Quebec Harbour, 8 fathoms. The entrance to Quebec Harbour is a typical example of a channel crossing a cuesta, and it has at least 8 or 10 fathoms of water. It would appear, therefore, that wave action, [illegible] with the strong currents which move into and out of the harbour under the influence of the wind, are sufficient to excavate channels of a considerable depth, although the first result of wave action alone is merely to reduce the rocks to a flat surface very little below the [illegible] level.[1] This must be thought to be the case in the absence of evidence to prove that the water of the lake ever stood at a lower level than now, which could hardly be premised without demonstrating the existence of level benches at a depth too great to be the result of wave action at the present level.

The strikes and dips of the laminae observed on Long island were as follows:

Location	*Dip*	*Strike*
100 paces from east end	17	275
West end		243

The rock on Long island displays good examples of the bleaching of the rock from purplish red to yellowish white along the joints.

[illegible]

The depth of 20 fathoms, already mentioned on the north side of these islands, occurs on the south side, as charted, a considerable distance out, and no greater depth is shown between Long island and Cariboo islands some thirty miles to the south.

Stack island is separated from Long island by a channel whose direction corresponds, not to the direction of the joints, but rather to that of the strike of the laminae, which here bends toward the south across the general strike of the flow. Stack island also no doubt represents a lower part of the flow. The jointing is very prominent on this island, as well as on Long island. The bearing of the joints is 315°, and where excavated by the waves on the level terrace adjoining the south shore they form long trenches, like little canals, as much as 100 yards in length. The rock is much the same as on the other islands already visited; the direction of lamination at the west end of the island is 60° dip, S. about 60°.

On Ship island, about a mile and a quarter west of Stack island, the cuesta formation is not so apparent, the whole island having been worn down to the level of the terraces already described and presenting a low flat appearance, nowhere more than 15 or 20 feet high. The same difference in rate of increase of depth off the north and south shores elsewhere observed holds here. Lamination is quite irregular in direction; the strikes and dips observed were as follows:

Location	*Strike*	*Dip*
S. E. point	45°	
W. point	66°	35°
Average	50°	

Two principal directions of jointing were observed, viz. 298° and 340°.

On Green island, which is nowhere of great height, the laminae strike 47° and dip about vertically. This island has a gravel beach on its northern side, the only beach noticed on the entire group. A small island to the west of it has been split into four islets by two large eroded joints crossing at right angles and forming canals through the island.

The most western island visited, one of the so-called Gull Rocks, is low and does not exhibit the distinct formation found in other parts of this flow.

The rocks which flank the entrance to Quebec Harbour belong to the flow which extends along a great part of the south coast of the island and furnishes most of the chalcedony found upon it. It varies in colour and texture from a black vitreous to a dark grey or greenish felsitic rock, both varieties exhibiting a tendency to columnar structure in parts. The islands within the harbour mouth also belong to this flow. On the south side of Agate island the rock is fairly distinctly marked by columnar divisions, and is black and vitreous in appearance; on the north side it is much more slaty in texture and grey in colour. Large amygdules filled with chalcedony and agate occur, and also small veins of chalcedony. There are other amygdules filled with crystalline red feldspar and with a green earthy material. The amygdules here are very large and apparently represent a "basal amygdaloid,"[1] a feature which also appears at other parts of this flow, and throughout the formation. The felsitic parts of the rock on this island are less columnar than the vitreous parts, but on the next islet to the west the felsitic trap shows well developed columnar structure, the columns varying in position from horizontal to a dip to the north of 70°. On Fisherman's island, the largest of the group, there is a vein of red feldspar running east and west and containing brecciated fragments of the wall-rock. The island south of Fisherman's island has rock of a compact texture and well marked columnar structure, and the same description applies to the rock on the point at the west side of the harbour mouth. The rock on the lighthouse point is black, resinous-looking, traversed by cracks which suggest columnar structure, and affects the compass. This band is no. 2 on the map.

Following the harbour shore eastward from the lighthouse, a peculiar detrital rock was observed lying between no. 2 and the next igneous bed, and consisting of a fine-grained

green matrix containing angular fragments of the red felsitic rock below; the bed is of an inconsiderable thickness occupying [illegible] of shore and is followed by the reddish brown [illegible] rock with green spots which forms the bed of the [illegible] northern shore. This rock appears on the south shore of the harbour as far as the fishing station of the Booth Packing Company, beyond which no rock exposures [illegible] of the harbour until a point on the [illegible] considerably west of the old mining company's [illegible] is reached where the same rock is exposed. It shows [illegible] with laminae from one to four inches [illegible] vertical. The western end of the [illegible] up of the under

[illegible] northward from the bay wall toward [illegible] higher elevation [illegible] an exposure whic[illegible] [illegible] portion of [illegible] inclusions of the rock immediately [illegible] their [illegible] rock with patch[illegible] out of phenocrysts, and inter[illegible] to be porphyses of the overlying flow. Immediately beyond these exposures a well marked terrace [illegible] of which the top has an elevation [illegible] harbour. The level at the foot [illegible] General [illegible] between this point [illegible] porphyry [illegible] extension under [illegible] to be [illegible] to find [illegible] occur [illegible] of Chemo[illegible]

[illegible] and therefore of its outlet, flowing through a channel [illegible] soon in this hill as explained on page 17, and the summit of the trail, lying considerably below the hills on either side, is [illegible] about 330 feet above the lake. The direction of the pass through which it runs is about 30°. The rock at the summit is the same black rock of resinous or pearly lustre pitted [illegible] and conchoidal fracture seen at the top of the flow. Along the south shore of Channel lake the rock forms cliffs [illegible] 100 to 200 feet high, exhibiting a well marked columnar structure. In places at the foot of the cliffs the rock is more vitreous, and greyish or greenish in colour, with red streaks and spots, and also with a red "paint," which appears to be [illegible] mainly iron oxide, marking its joints. The north shore of Channel lake rises by richly wooded slopes to a high ridge, [illegible] reached at a point just opposite the landing on the south side [illegible] a defile through which a trail leads north. The highest point of this defile is about 300 feet above Lake Superior, at which level it expands, on the north side of the ridge, into an extensive level grown up with alder. The rock of which this range is composed is very similar to the top part of the flow on the south side of Channel lake, showing, if anything, a more closely pitted surface and more vitreous lustre.[1] A remarkable feature of these hills is that, contrary to the general rule, they exhibit along their southern slope near the base a line of cliff facing south, which might be referred to erosion by the water when at that level, but has no apparent level bench at its foot. It therefore seems likely that it marks the line of a fault, similar to those observed by Lane on Isle Royale, hading south and with its down-throw on the south side,[2] the line of fault being parallel to the strike. Lack of time, however, prevented a closer examination. The pitted rock seen on the shore is the only one encountered in the defile between the hills (exposed at 850 paces north of the lake) which militates against the supposition that the irregularity is due to [illegible]

that or not the objects are not now bituminous. They have a fibrous structure which recalls the cone in cone concretions of the upper division of the St. John group, which, now in carbonaceous shale, were probably at first in bituminous shale." See Fig. 3.

North of this belt the black melaphyre of Channel lake succeeds, here at its southern edge displaying occasional large amygdules filled with quartz crystals or chalcedony. The weathering of this rock here also takes on spheroidal forms composed of concentric layers which weather off one after another pearinte fashion. From the contact, the road follows the lake at the level of the lowest raised beach, about 15 feet, the same rock outcropping on the north side of the road, for about a quarter of a mile, then turns away from the lake and ascends to a level about 15 feet above the lake, where the same rock, here exhibiting a distinctly porphyritic character, is exposed for a distance of 177 yards from the lake, when the contact with the underlying red porphyry is reached. The road follows the contact for some distance, the two rocks being alternately exposed as far as 678 yards from the shore where the last outcrop of the melaphyre was passed. The level here is about 70 feet. At the edge of the next porphyry crest the height is 210 feet, and the swampy bowl and immediately succeeding is at about 180 feet. The thickness of the crest porphyry flow here passed is estimated at 130 feet. The dip at its southern edge is 20°. According the slope of the next outcrop levels occur at 290, 230, followed by a valley cut down to 180, and finally the ridge of the crest rises to 325 feet. A lower level of 80 feet follows, and the northern edge of the flow rises again to 260 feet, then drops off again to the outlet of the first lake at 235 feet. The total thickness of this second flow of quartz porphyry at a dip of 20° is estimated at about 1100 feet. It is immediately succeeded by another, more apparently a thin layer of red porphyry. The thickness both here is estimated at 1303 feet. On the flank of the ridge marked levels occur at 310 feet, at the lake which follows at 1100 feet, at 300 feet. The

quartz porphyry here is succeeded by a completely crystalline olivine-diabase, and this in turn by a succession of thin beds which may be described as (1) pitchstone (diabase), (2) quartz porphyry, (3) melaphyre (amygdaloidal at the top), (4) altered olivine diabase, (5) "lustre-mottled melaphyre," all of which occur along the shores of the lake. Their dip is not apparent but may be taken as about 30°.[1] At this dip they have a total thickness of 1575 feet. On the road between this lake and the Quebec mine, for a great part of the distance the rocks are covered with soil. The 300-foot level is maintained for some distance, to a point about 1,000 yards from the mine opposite a large hill on the west, when the descent begins and continues to the lake. Dr. Coleman has noted outcrops here at 233, 204, 128 to 178, 65 to 78, and 15 to 22 feet respectively. Below the lustre-mottled melaphyre bed last mentioned, there is a felsite flow verging upon quartz porphyry, having a thickness of 532 feet, and this is followed by a band of diabase porphyrite of 463 feet, which forms the base of the lofty hill to the west of the road (thickness estimated for 40° dip). Below this flow there follows a slope covered by soil, which is probably underlain by three distinct beds, a conglomerate, a porphyry, and a "lustre-mottled" rock, of which, however, only the conglomerate and the porphyry are exposed. The total thickness of the three is at least 1140 feet, measuring to the summit of the cliff behind the houses at the mine, which is composed of an amygdaloid conglomerate. This is followed by a lustre-mottled rock, this in turn by a diabase, and this by an amygdaloid which forms the lowest exposed rock, on the point in front of the old house used as a powder house. The thickness of these beds to the water line may be fixed with considerable accuracy at 1045 feet.

3) *Section exposed on the shores in passing round the eastern end of the island from Quebec Harbour to Quebec mine.*—Leaving the lighthouse at the harbour mouth and proceeding [illegible]

along the shore the same flow is exposed on the shore and islands lying along it for six miles. On the islands lying [illegible] east of the harbour it is traversed by veins of calcite [illegible] bearings 183° and 228°. The courses which [illegible] latter direction are filled with brecciated fragments [illegible] rock. The rock weathers out on both sides of the veins, which stand upright in the centre of the troughs thus formed. The dip is about 14°. Much of the bed exhibits columnar structure, either distinct or incipient, in some places the cracks [illegible] of columns, in most parts the [illegible] red [illegible] to the weathering out of [illegible] in the rocks. In the wide [illegible] Harbour [illegible] the largest is [illegible] feet in width, has a central band of [illegible]

[illegible]

[illegible] Cambrian basal amygdaloids." Somewhat similar bodies, [illegible] fossil forms even more closely, have been d[illegible] by M. E. Wadsworth, and ascribed by him to non[illegible]

An undoubtedly pyroclastic rock was obtained [illegible] Coleman from this locality, and very probably immediately [illegible] underlies the pitchstone bed, but was not observed by the [illegible] As the existence of pyroclastics in this formation [illegible] been doubted by Irving, who ascribes all the lavas of thi[illegible] to fissure vents without explosive action, this specimen, [illegible] in the collection of the School of Practical Science, Tor[illegible], is of importance.

Further eastward the pitchstone flow occupies the shore [illegible] the south-eastern point of the island, with the ex[illegible] of Cozens Harbour and the small bay just west of it, [illegible] northern shores are composed of the red rock of Quebec [illegible] our, here a quartzless porphyry with well developed [illegible]. This rock is again exposed on the eastern shore [illegible] island and is followed to the north by a band of grey [illegible] of felsitic texture corresponding to the rocks of Chan[illegible] lake, which extends as far as the north-east point. Along [illegible] western shore this is followed by the softer porphyry [illegible] and the olivine diabase in the same order observed on [illegible] road from Quebec Harbour to the mine, and following [illegible] the 'ordinary' diabase and the narrow quartz-porphyry [illegible] below it are exposed twice as already explained.[2] A [illegible] base which succeeds the quartz porphyry occupies the [illegible] as far as the western boundary of the Bonner location, [illegible] re the peculiar reddish altered rock underlying it on the [illegible] llows. From this point to the mine the series is some[illegible] difficult to follow, owing to the occurrence of gravel [illegible] ricked by earth terraces, but there seems little doubt [illegible] ll of the igneous beds can be accounted for, nos. 18, 19, [illegible] being exposed in that orde[illegible]:

The [illegible] at the north-east point of the island form[illegible] high range of hills, but the quartz porphyries to the west of them are uniformly low, the large flat in the centre of the island between Channel Lake and Lake Superior being covered to the shore at this part of the island. The contact zone of the three porphyries shows forth as a low country which reaches the shore at a mile and a half east of location Y40. At the point on Y40 some pieces of St. Mary's conglomerate were found, and this rock appears to underlie the water a little to the east of here, lying in the level ice-worn rock which underlies the channel between the island and the north shore. There seems to be nothing in the relation of these rocks which would suggest a fault running along the north shore of the island, and the trend of the coast-line is rather to be determined by the strike and weathering qualities of the rocks than by a fault line, which, one might expect, would follow a more regular course. Were a fault present in line with the northern part of the island, and the receding of the coast to the east due to erosion, the sandstone would not be found so far south as location Y40. These considerations are of interest in view of the detection of the existence of a fault in the south-east side of the Keweenawan rocks of Keweenaw Point, whose formation recalls that of Michipicoten island, in other details as well as in the relationship of these two classes of rocks.

Table of Stakes and Posts

[illegible]	Stake	Post
[illegible] of [illegible]		1, S
S. E. 1 mile W. of Coven Harbour	[illegible]	2, S
N. Bore Coven Harbour	[illegible]	3, S
Two miles W. of Y40	[illegible]	4, S
Point on Y40	[illegible]	11 S
L. boundary Bonner location	[illegible]	11 S
Bay on Y38	[illegible]	5, S

[illegible] Westward from the harbour

[illegible] the pitchstone flow continues for about two miles to a point [illegible] west, after which it reappears again on two small islands 2 [illegible] and 3½ miles farther west. In the bay which follows the point the red quartzless porphyry of Quebec Harbour is exposed, and is succeeded by an argillite as already described, [illegible] the road skirts the shore, and this in turn by the [illegible] pitchstone diabase porphyrite of Channel lake. On [illegible] June [illegible] just west of here it is a black, vitreous-looking [illegible] with a tendency to columnar structure, and traversed [illegible]. Similar rock appears to occupy the shore as far [illegible] point, where a fine columnar exposure exists. [illegible] the curving shore toward the south-west point of the [illegible] the amygdaloidal quartz porphyry comes to the shore, [illegible] point to the west this is [illegible] by [illegible] currence [illegible] columnar-like rocks in columns [illegible] point [illegible] faces, black vitreous lustre and conchoidal fracture [illegible] and [illegible] dikes [illegible] similar to [illegible] the [illegible] end of the island. Some fragments of [illegible] stone occur here, probably [illegible] mentary [illegible] exists between the pitchstone porphyrite and the quartz porphyry which succeeds. The quartz porphyry is here [illegible] nearer to a felsitic character, the phenocrysts being [illegible] very small [illegible] laminar structure apparent. It is followed to the north by a very coarse conglomerate, having boulders of Laurentian and Huronian origin as well as those derived from the Keweenawan, the whole cemented with calcite. Thin flows of quartz porphyry seem to occur at intervals through the conglomerate exposure, which occupies [illegible] a quarter of a mile in width. It is followed on the north by a quartz porphyry, the lowest of the three observed together elsewhere. Following this are diabases which here exhibit a columnar structure. A number of bands are probably concealed from this point on, under the gravel beach of the most northerly of the two bays on the western end of the island. At its northern point a massive black diabase is exposed, probably corresponding to that observed in the large hill

[illegible]

south of the Quebec mine. Below this is another conglomerate of similar materials to the first, which is followed by a fine grained reddish flow and this by a "lustre-mottled melaphyre" which occupies a great width on the north-west point. Below it is an amygdaloid agglomerate, immediately succeeded by a conglomerate composed of Keeweenawan materials, whose upper part has been mined for copper at the south-western point on the Jones location. Following the shore northeastward toward the mine, this is succeeded by another band of lustre-mottled rock. Following this is a diabase with an amygdaloidal belt above it, a red felsitic flow, another diabase, and finally an amygdaloid, on the point near the cave at the mine. These lower beds are all quite thin and dip about 55°. Of all the rocks on the west end of the island, it may be said that they dip steeper and show a much finer grain than in the more easterly parts of the same bed.

TABLE OF STRIKES AND DIPS

Location.	*Strike.*	*Dip.*
S. shore opposite Stack Island	85°	18°
Southwestern point	90°	32°
About ¼ mile N. of S.W. point	30°	70°
S. side of N.W. point	94°	84°
N. side of N.W. point	107°	38°
Phillips shaft	55°	50°
Between shaft and shore	65°	15°
Shore half way from Phillips mine to Quebec mine	90°	35°
Point in front of cave	58°	56°

IV. PETROGRAPHY.

1.[1] This flow is represented on the islands to the south of Quebec Harbour. The rock has been described by Irving as identical with that at Mount Houghton on Keeweenaw Point, [2] Porcupine mountains, in Michigan, and on the Minnesota coast of Lake Superior, but here occupying a higher

position than elsewhere. His microscopic description is as follows:—"The groundmass is nearly colourless, cloudy, and thickly dotted with very minute ferrite particles, which at times aggregated into waving lines. In the polarized light feebly polarizing flecks dot a dark background, some of which are recognizable as quartz-network clusters; no porphyritic ingredients in the section." A number of sections examined enable the writer to add that this even texture is varied at times by augite grains, tabular plagioclases, and aggregates of highly refracting crystalline quartz, the first two generally rare, the latter sometimes quite large and numerous, but not in clearly defined crystals, and probably of secondary origin filling cavities.

2. The variations in the 'pitchstone' flow along the south coast have already been partly described. Irving describes five sections of this flow, including probably all of its important variations. There is in general a glassy groundmass, filled with more or less developed plagioclase microliths, augite grains and magnetite particles. This represents the pitchstone phase. In felsitic varieties these constituents are enlarged as to fill nearly the whole area, the plagioclases assuming a tabular form, while the porphyritic varieties have a matrix closely resembling the glassy phase, with phenocrysts of plagioclase, augite, and magnetite. The rock may therefore be described (see Irving) as a diabase porphyrite, although in the felsitic parts, which are nearly wholly crystalline, the ophitic structure is not present. In some varieties, probably belonging to the basal amygdaloid, or what corresponds to it, in this bed, the tabular plagioclases tend to assume a common direction. The felsitic parts of this rock are interbedded with glassy parts, neither occupying a distinctive position in the flow. The veins which are formed throughout this flow are probably, to some extent at least, alteration bands, being made up largely of brecciated fragments of the rock itself with interstices filled with quartz and calcite. The augite in such cases is represented by hornblende, and the residuary magma by iron oxide and chloritic material.

5. The pyroclastic specimen obtained by Dr. Coleman from the south-east shore of the island probably belongs to the base of this flow. It is composed of dark green lapilli of rounded form embedded in a lighter green serpentinous material, and is distinctly different from the breccias described by Macfarlane, which occur lower in the series and are probably, as Irving maintains, of a different origin. The materials in Dr. Coleman's specimen are certainly more closely related to the basic bed near which it occurs, while Macfarlane's breccias are connected with the quartz porphyries both in position and composition.

Between the pitchstone bed and the quartzless porphyry of Quebec Harbour, a thin band of sedimentary origin intervenes. At Quebec Harbour this consists of fragments of the [illegible] porphyry embedded in a matrix made up of fine [illegible] and chloritic material. At a point at the east end of the broad bay west of Cozens Harbour, a finely laminated siliceous argillite with much calcite in crystallized lenses is exposed running across the base of the point.

The quartzless porphyry found at Quebec Harbour and eastward corresponds to the rock called by Macfarlane porphyritic melaphyre and described by Irving (p. 346). The section described by him, however, seems to have been taken from a bed lower in the series. In common with many other flows on the island, especially the acidic ones, this bed is fine-grained at its western end and at Quebec Harbour, while toward the east its phenocrysts are large, up to ⅛ of an inch and at the east end of the island it displays large phenocrysts of quartz corroded by the base, altered orthoclases, and oligoclases with a matrix showing alteration to secondary quartz (See Fig. 5). This also is described by Irving and by Macfarlane as occurring confusedly, but there seems no doubt of its belonging to the same flow as the rocks of Quebec and Cozens Harbours[1] (See Fig. 5, no. 1).

6. The slate or porcelainite bed which follows has a dark grey, very fine-grained appearance and breaks easily into

mall irregular fragments. It contains rounded pebbles of the diabase porphyrite just beneath it and of the quartz por- ries which lie below them. The matrix would seem to be hiefly composed of the materials of the first mentioned rock fine state of subdivision. Its present appearance give e impression of change due to the heat of the flow above it, roducing the porcelainitic character

7. Diabase porphyrite extends from the south-west corner of the island to its north-east corner, and is largely exposed long the south shore of Channel lake. This rock is undoubt somewhat simliar to the bed at the mouth of Quebec Harbour with the exception that augite is more prominent both the felsitic and porphyritic phases. The upper part porphyritic, the lower more felsitic and columnar. A tion taken from the south shore of Channel lake near the tern end shows a nearly colourless groundmass filled with eat numbers of magnetite grains and green chlorite grains, the whole polarizing dark. Quartz grains seem in parts to a net rk. A few grains of pyroxene occur. The ppearance of the rock microscopically varies from a black inous porphyrite with pitted surface to a dark grey or grey- n felsitic rock with no phenocrysts apparent.

8. On the north shore of Channel lake a very fine example of diabase porphyrite occurs. It has a black matrix of resinous tre and cherty fracture and many phenocrysts of well riated plagioclase and magnetite visible to the unaided eye, ich weather out, giving the surface a pitted appearance. hin section shows a colourless or light brownish ground ss sprinkled with magnetite grains and with much more merous microliths of plagioclase forming an almost con- uous network. In this are large phenocrysts of augite metimes twinned), olivine, magnetite and plagioclase, the three usually associated, the plagioclase separate, also leite (?) in the section examined showing a fine spherulitic rrangement with wandering extinction (Fig. 5, No. 2).[1]

...ian seems to occur on the other hand at the base of a ...ic flow. As to the position of the acidic "breccias" there ... be no doubt, as this form of rock is found at the south ...t corner of the island and on the road to the Quebec mine ... the top of the acidic series. In the latter case the matrix ... basic as on the north-east shore, and the breccia occurs ...mediately below a diabase and at the top of the uppermost ... the quartz porphyry flows.

As to the lower part of these flows they seem to follow the ...eral rule observed already, being felsitic in appearance and ...minated at the west end of the island with very few if any ...ible phenocrysts, and porphyritic at the east end. The uppermost of the three flows consists of quartzless porphyry at the road, but on the shores of Coldwater lake shows well ...eloped phenocrysts of both quartz and orthoclase. The ...hoclase in these cases develops first so that the rock, as in ...se of the Quebec Harbour rock, passes through quartz ... into quartziferous porphyry. In these cases the quartz porphyry commonly shows a large amount of secondary ...tz, filling cavities or forming a network in the groundmass.

11. A flow similar to no. 10, but not so well exposed on road.

12. A thick bed of conglomerate intervenes between two ...orphyry beds at the west end of the island. The pebbles ... rounded and run up to several inches in diameter. The matrix is partly calcite, and partly reddish brown material derived from the Keeweenawan flows adjacent. The pebbles ...luded are (1) biotite gneiss of Laurentian origin, (2) green-...nes, possibly Huronian, (3) reddish and purplish porphyries ...d amygdaloids from Keeweenawan sources. This bed ...nds only a short distance inland.

13. This porphyry flow, the lowest of the three already ...ntioned, develops a definitely porphyritic character farther ...west than the upper ones, showing fairly large quartzes where ...d by the road. It has a brecciated upper part with ...ic filling (see under 10), which was observed both on the ...tern shore of the island under the conglomerate and at ...utlet of the most southerly of the two lakes on the road

the rock probably exhibits porphyritic phases in other parts. The specimen observed was obtained at the road.

21. A dark grey or chocolate grey rock, quite fine-grained, follows, forming the hill [illegible] south of the Quebec mine [illegible] exposed at the north point of the small bay about [illegible] scale south of the north-west point of the island and probably [illegible] At the west end it displays very little, if any, porphyritic structure. The section shows merely a pale yellowish magma flecked with darker grey, the whole showing a parallelism due to flow or pressure and dotted with magnetite grains.

[illegible] of the flow last mentioned a second conglomerate is exposed on the west shore. It consists of a greenish magma, probably derived from the basic flows below it, contains rounded pebbles of granite, purple and flesh-red porphyries, and of a fine-grained green basic rock. This [illegible] probably extend as far as the road which crosses near the site of the burned farm-house just south of [illegible]

[illegible] A purplish felsite follows the conglomerate, having apparently a brecciated upper part.

[illegible] This is succeeded by a lustre-mottled melaphyre or epidiorite, which occupies a great breadth on the north-west point of the island, where it in parts displays columnar structure. It crossed by the road it lies just south of the cliff at [illegible] is not exposed. The characteristic nodular surface is well shown on this flow. A considerable amount of "original magma" is present between the augite areas, and is stained dark by iron. Magnetite occurs in large amounts [illegible] not always very conspicuous being largely replaced by chlorite. The lower part of this bed is not exposed [illegible] on the north west point of the island and is coarser grained, the plagioclase crystals being visible [illegible] conspicuously. The olivine is largely altered to chlorite [illegible] Other areas of chlorite bounded by [illegible] plagioclases may represent "original magma." The [illegible] is not [illegible]

25. This is the rock which forms the cliff behind the mine and projects into the lake at the north-west point of the island. It consists at the top of irregular masses of purplish amygdaloid imbedded in a matrix of calcite and feldspar, gradually assuming a non-fragmental form toward the lower part. The amygdaloid has a dark brown, ferrite-stained matrix with microliths of plagioclase in places radially arranged. Augite occurs in phenocrysts, sometimes also in grains bounded by the plagioclase. There are large amygdules filled with zeolitic material radially arranged or with an outer band of zeolites and a central part occupied by striated calcite, and also pseudamygdules filled with calcite and fragments of the matrix. The lower part of the bed presents the character of an ophite under the microscope, having areas of optically continuous augite intersected in all directions by plagioclase crystals and separated by bands in which the interstices are occupied by a dark coloured base containing magnetite grains and in places chloritic alteration products.

26. The next bed is a conglomerate whose upper part has been mined for copper at the western shaft on the Jones location. Where exposed on a small island near there, the matrix is mainly composed of comminuted rocks of the series, with numerous pebbles among which the following rocks were noted: (1) dark purplish amygdaloid with parallel amygdules, (2) purplish quartzless porphyry, (3) reddish felsitic rock (phenocrysts not visible), (4) coarse amygdaloid, (5) fine-grained crystalline greyish rock, probably a melaphyre, (6) (in shaft) red sandstone. This conglomerate seems not to extend as far as the Quebec mine. The smaller fragments are angular, those over three-quarters of an inch in diameter are rounded.

27. An ophite quite similar to that at the north-west point, but more chloritic. This is the rock which outcrops between the Quebec mine and the cliff at the back of the

28. An ophite having a purplish red amygdaloid at it upper part. This is probably the amygdaloid in which the Quebec mine was worked. A sample of the ore obtained at the mill shows in the thin section the usual dark iron-stained ground mass with a network of plagioclase needles, augite nearly all altered to chlorite and iron oxide, some large areas completely filled with chlorite. No true amygdules are represented in the section, and the rock where mined seems not to be extremely vesicular.

29. A narrow band of reddish quartziess porphyry.

30. A dark green, fine-grained diabase exposed at the cave which is used for storing dynamite.

31. An amygdaloid exposed at the water's edge, near the cave.

In addition to the rocks forming the series two others are of interest.

1. The Lake Superior sandstone, which overlies the Keeweenawan on the bottom of the channel between the island and the mainland. It is a dark reddish purple with cream-white spots and bands of rounded outline. It consists of angular fragments of quartz showing few secondary enlargements, some feldspars, grains of iron oxide, and some chlorite filling the interstices.

2. The drift rocks on the island have as their most prominent constituent a biotite gneiss, which is everywhere in evidence as boulders. It is light in colour, the biotite being scarce, and contains some accessory plagioclase, olivine and [illegible].

[illegible]

Thickness.—The beds on the island already enumerated, with their estimated thicknesses, are as follows:

1.	Felsite of islands off the south shore	1000
2.	Pitchstone bed	[illegible]
3.	Quartzless porphyry of Quebec Harbour	600
4.	Melaphyre porphyrites of Channel lake	1000
5.	Quartz porphyries [illegible]	225
		1100
		1400

6.	Beds exposed at lake on road	1575
7.	Felsite	513
8.	Diabase porphyrite	463
9.	Beds underlying farm (3)	1140
10.	Several beds at mine	615
	Total	11,230

This thickness is somewhat less than Logan's estimate (12,000 feet), and considerably less than Macfarlane's which is 18,500 feet. The work of the latter was probably vitiated by his supposing a continuous series from the north-west corner to the south-east corner of the island where he places the highest rocks of the series. The discovery of Keeweenawan rocks on the north shore of Lake Superior opposite the island renders the thickness important, as a thickness of 25,500 feet on the island would require the lower Keeweenawan there to be regarded as much thicker than at any point determined by Irving. Taking the general strike of the rocks on the island into account, there seems no reason for supposing that the thickness of the rocks underlying the channel should be estimated at the extreme dip (55°) found at the north-west part of the island, for which the sharp curves of the beds suggest a local cause, but rather at the dips observed further east along the north shore, which range from 25° at the east end to 55° at the west. Taking the average 40° and the distance across the channel as 10 miles the thickness represented would be 21,000 feet, which with the thickness already estimated on the island would give a thickness of over 45,000 feet with probable additions to be made at the top of the series. Supposing the dip to be 30°, which is a fair average of the dips throughout the island, and above the average if we neglect the north-west part, the thickness beneath the waters of the strait would be 26,400, and the total 37,630, which is not far above the 35,000 estimated thickness of Keweenaw Point. The thickness of the lower beds on the island, which occur only at the north-west corner and run out on the north-western coast, would have to be deducted from this total, which would

thereby be reduced by 2,770 feet to 34,860.[1] This thickness would therefore appear as a minimum, leaving the steepening of the strata at the north-west part of the island unaccounted for. The fact that the beds at the eastern end of the island narrow considerably, while the dip remains low, makes it probable that the island represents an exceptionally thick part of the formation, and may be situated close to one of the original vents, from which the flows were extruded.

The rock observed by Dr. Coleman on the north shore between Pilot Harbour and the Pukaswa river was a basal conglomerate lying unconformably upon the Huronian and composed of Huronian and Laurentian material.

The above considerations make it appear possible to account for the total thickness of rocks here without supposing a great fault along the north shore of the island.

The island as a whole might therefore be considered as somewhat similar in formation to the Niagara escarpment. In both cases the beds first laid down on the flanks of the geosyncline have been worn away for some distance to a plane which slopes gradually away from the archæan rocks, until beds are reached of sufficiently resistant power to form an escarpment, in this case the wide group of basic beds of the northern part of the island. If we suppose the lower part of the series now submerged to be chiefly acidic, which agrees both with the materials found in conglomerates on the island, and with the observed facts as to the lower part of the formation elsewhere, we may readily suppose them to have had comparatively low resistant powers, as this is so evidently the case with the acidic flows on the island itself. The gradual upheaval of the edges of the synclinal during the period of deposition[2] has been held to account for the gradual steepening of the dip shorewards, found alike on Keeweenaw Point, Isle Royale, and Michipicoten. In this direction a possible explanation of the peculiar curve southward of the beds at the west end of the island may perhaps be found. The western

...d of the island lies, as has been stated, almost opposite to ... centre of the curve of the coast from a west to a north-west ...rection. This bend forms a re-entrant angle in the edge of ... great synclinal trough of Lake Superior. If we suppose ... trough to have been subjected to lateral pressure, such as ...ould tilt up the flows around its edge, we must also suppose ...t the resultant of such constriction exerted from all sides of the trough would be exerted in a direction parallel with its ...gin. The points at which such a pressure could most ...ily gain relief by folding would be at exactly such a re ...ntrant angle. The result of pressure exerted from the east ...ting against pressure from the north-west, would evidently ...be the raising of the rock at the point of impact of the two ...ces with a tendency to move them in a south-westerly ...irection, and the natural result would therefore be an anti ...inal fold having its axis in a direction west of south, and ...ning in the same direction. If we imagine such a fold ...enuded, the steepest dips would not be at the apex of the ...ld, where they would exceed, however, the general dips along ...e coast, but upon its flanks, and the observed facts here ...rrespond exactly to this. As we approach the fold along ...e strike of any given bed the dip of the bed increases, simu ...ting a twisting of the beds, reaches a maximum of 55° at the ...uebec mine and falls again to about 35° at the western end ... the island, which represents the apex of the anticlinal. The ...stern side has disappeared beneath the surface of the lake ... his hypothesis would also account for the progressive opening ...sures indicated by banded veins on the south side of the ...

If we examine a map of the Lake Superior synclinal,[1] a ...eneral triangular form is to be observed. About the middle ... the three sides of the triangle are three such re-entrant ...gles. The longer south side has a large one represented ... Keeweenaw Point with its continuation to the south-east ...ard through Stannard's Rock. The shorter north-east and ...th-west sides are indented by points outside of which lie

[1] [illegible]

[illegible] Keeweenaw Point [illegible] Michipicoten island, shows on a [illegible] The [illegible] perfect the greatest dip shown on Irving's [illegible] of Portage lake. Dip of folds is 55° and the dip [illegible] Copper Harbor at the northern end of the point is 30° [illegible] of the antiennal which in this case is [illegible] Vape. This theory would also account [illegible] strike of the Keeweenawan in the [illegible] At Michipicoten island the copper [illegible] beds parallel to the strike and occur [illegible] of the fold, not at its apex. On Keeweenaw Point copper is found in beds and transverse veins. The [illegible] only near the north eastern end of the Point [illegible] summit of the fold, while the beds as at Michipicoten occur on its flank. On Isle Royale the only copper [illegible] are in transverse veins. The rock mentioned in [illegible] part of this paper from Thunder Bay containing copper is part of a flow and may represent the bedded deposit [illegible] fold. The promontary of Mamainse is probably [illegible] fold of the same nature. The copper there occurs in [illegible] veins. A sort of subsidiary fold appears in the [illegible] mountains to the west of Keeweenaw Point, and [illegible] causes the repetition of one of the beds (*supra* p. [illegible]) on the north east shore of Michipicoten island.

These considerations suggest further reflections especially as to the origin of the transverse veins. Irving has ascribed them solely to alteration, but their general position at the summit of such folds would certainly point to tension or contraction, while allowing sufficient time in the opening of the fissures for the brecciated material of their walls to be retained in the vein stone, and even for a considerable amount of such [illegible] he describes to go on along the sides of the fissure, accounting for the differences in width in the same vein in

The thinning of the flows upon the flank
quite marked at Michipicoten as on Keeweenaw
deposition of copper in the flows at these point
connected with the alterations produced under
t tension to which these beds must have been sub
during the formation of the fold

uestion of the faulting which might be exp
formation of such a fold, and its comparison wi
faults known to exist on Isle Royale and Keeweenaw
es not come within the scope of this paper, except
the latter would be greatest at the edge of the synclinal
be expected

The deposition of the conglomerates, which are evidently
ociated with the fold at the west end of the
ps be referred to the raising of the roc
en would cause the curved beds actu
d down upon the seaward side of the emergence

The felsitic nature of the igneous flows at this point,
farther east display a porphyritic character, may be
by their comparative thinness over the arch of the
ually rising anticlinal

The succeeding flows may, therefore, be said to lie to a
in extent unconformably upon one another, and the
ones form part of an arch of much broader and more
slope than that seen in the lower This may perhaps
count for the fact that as we cross the island from north to
the felsitic or glassy character of the rocks extends
t

Here as at Keeweenaw Point a horizontal sandstone lies
conformably upon the lower members of the series. At
Michipicoten, however, it is not possible to observe its relations
fully, but it would seem probable that the situation here
ers from that to the south and east of Keeweenaw Point
that the Keeweenawan rocks appear on both sides of the
sandstone. South of Keeweenaw Point its shoreward edge
covered by newer strata, so that it is impossible to observe

the lower limit of the Keweenawan deposit—even if the contact could be proved to be—appears to be the case at Michipicoten—laid down in a trough whose edges on both sides were sandstone.

Among the igneous rocks on the island, apart from those still undescribed by Irving, seem to be almost entirely of the ophitic variety known as lustre-mottled melaphyre, olivine diabase, or ophite, with their accompanying amygdaloids. So far as the writer was able to determine without analysis the rocks provided the same chemically, or quite nearly so, as the ophitic or diabasic porphyrites of Council Lake. The general connection of the formation is not noticeable on the island on the southern shore with the outlying structure about Isabella Lake, as indicated by the fact that these rocks have been more or less transverse to the flow in following it from east to west, and that their dip to the south corresponds closely with the dip of rocks at the north west part of the island, while their position would seem to be at right angle to probable line of pressure. The amygdaloidal rocks described by Irving are also in part situated in folded parts of the formation, namely the Porcupine mountains and Mount Houghton on Keweenaw Point, but do not show cleavage parallel to their bedding, as these rocks do.

APPENDIX I

Table 1

Glacial Striæ

At east end of the island 171 and 202

Table 2

Directions of Joints on south shore

Cozens Harbour	115
Long and Stack Islands	135
Shore opposite Stack Island	170 and 172

Table 3

Bearings of veins on south shore

Cozens Harbour	93
Cozens Harbour, two veins	98
West side of wide bay west of Cozens Harbour	105
Islands immediately east of Cozens Harbour	188 and 228
Conglomerate at west end of the island	229

APPENDIX II

Extract from *Science*, Vol. I, No. 8, March 20, 1880.

I think, if Professor Irving could visit Michipicoten Island, he would be able to recognize plenty of volcanic detrital matter or tuffs, among the copper bearing rocks. The vast area over which I have examined the elder members of the newer tertiary volcanoes of Australia enables me very readily to recognize such rocks when seen, but their occurrence at Michipicoten, and elsewhere on the north shore, is no proof that they also occur to the south, and therefore I fail to see how Professor Irving should dissent from my statement on this point.

Signed ALFRED R. C. SELWYN.

APPENDIX III

Irving, *Copper-Bearing Rocks of Lake Superior.* Index references to Michipicoten Island

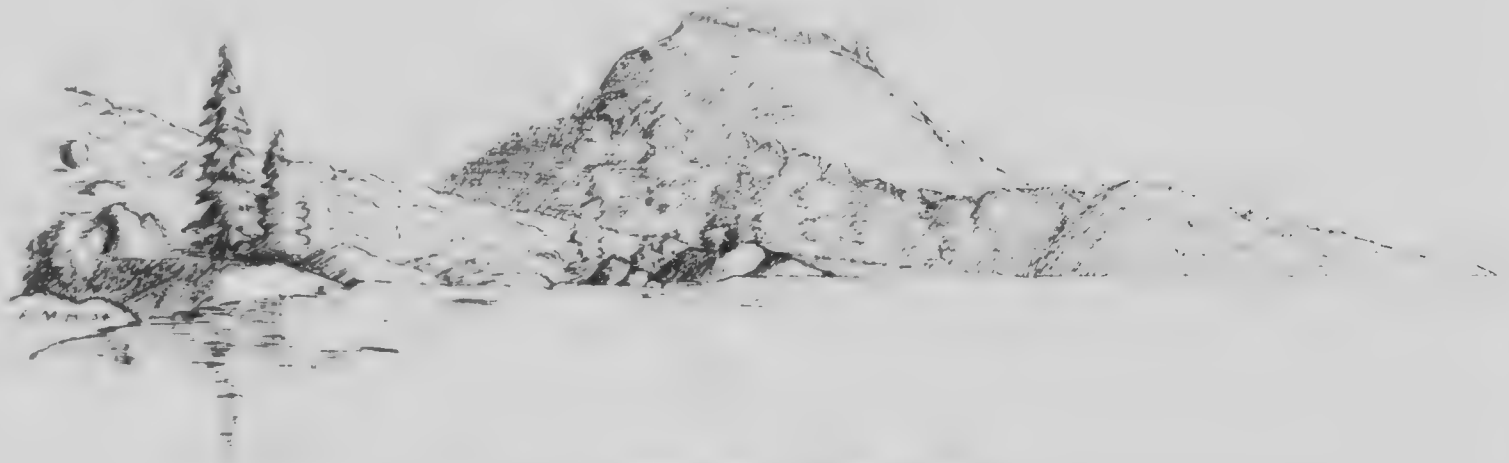

FIG. 1.—EAST END OF COOK'S HARBOUR.

Shows the general character of the country to the south. Height of the background consists of the flow marked *z* in the map; the slope to the left forms that marked *y*.

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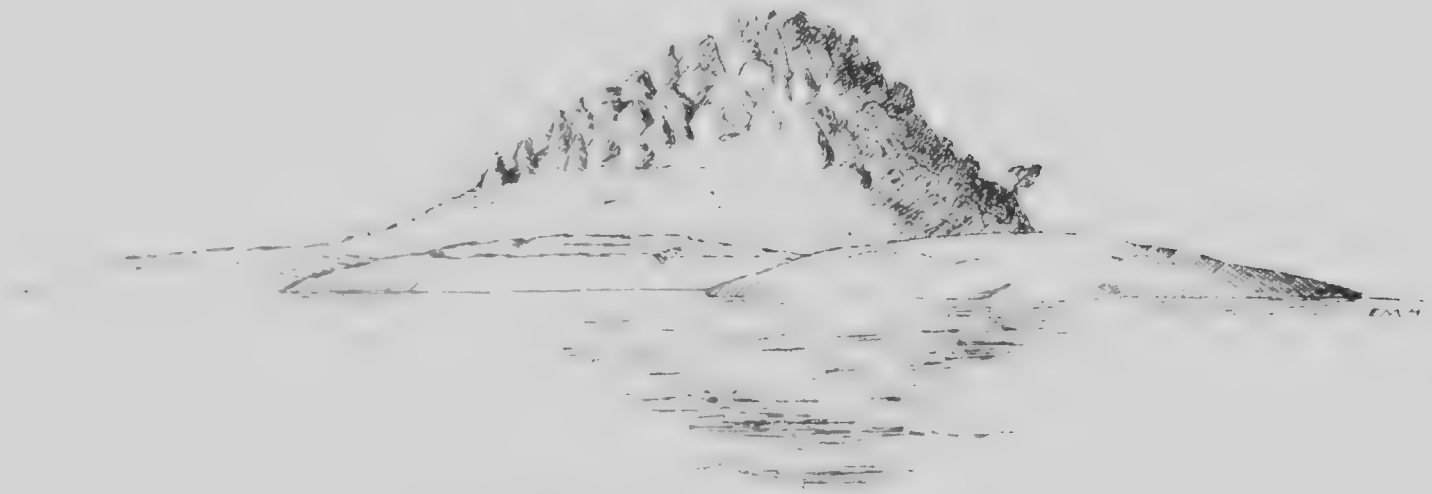

FIG. 2.—LONG ISLAND FROM HOPE ISLAND.

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FIG. 3.—PSEUDOFOSSIL.

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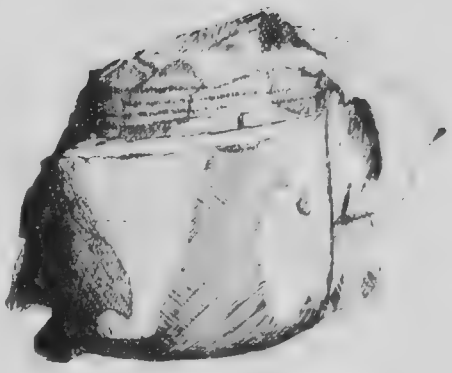

FIG. 1. SPIKE AMPOULE

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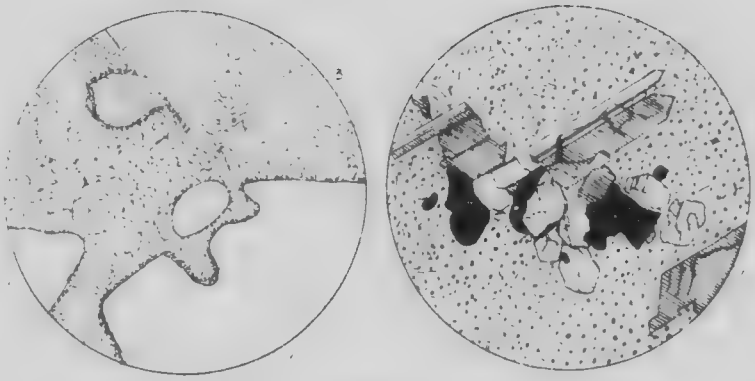

FIG. 5

Quartz porphyrite east end of Mesaquoteen Island
1. Quartz phenocrysts eaten by matrix and outlined by magnetite grains
2. Altered clouded, and fibrous looking orthoclase
3. Matrix in heating partial outlining of quartz network by magnetite grains

Dacite porphyrite north shore of Channel Lake. Plagioclase shown as a between N. Magnetite black, wavy lines to Mag netite grains and minute plagioclases in base

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FIG. 6.

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SECTION AND PROFILE FROM QUEBEC MINE A TO GULL ROCK B. See Map Inset

Vertical and horizontal scales equal. Hard ground represented [illegible] dotted [illegible] Levels increasing northwards. Figures heights above lake in feet; hatching and [illegible] as on map.

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NOTICE OF

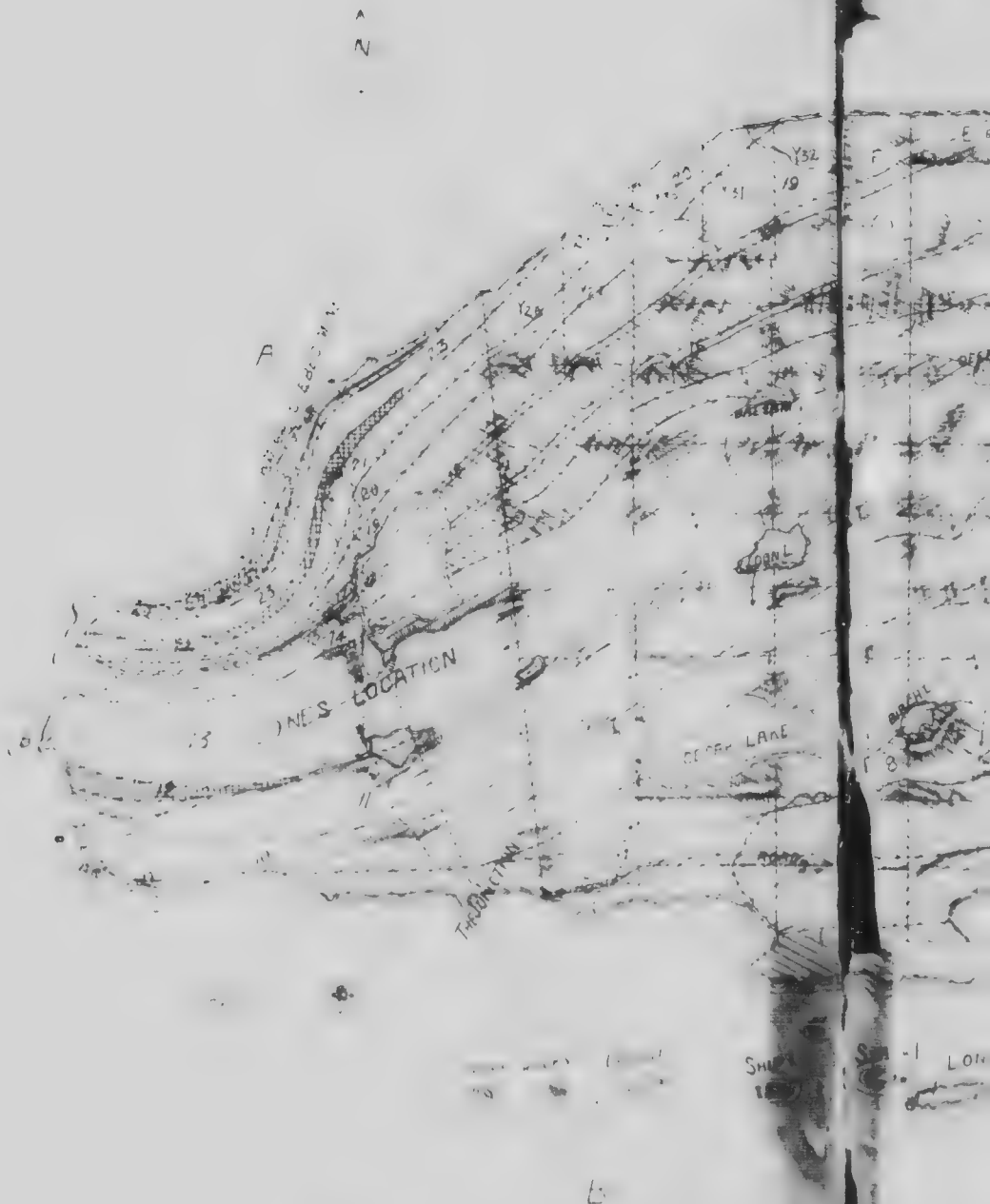
PICOTEE ISLAND.

Ba[illegible]

Acco[illegible]

Sa[illegible]

D[illegible]


N
Y32
19
LOAN L
JONES LOCATION
DEEP LAKE
THORNTON


BONNER
HARBOUR
LONG I
CHIPICOTEN ISLAND.

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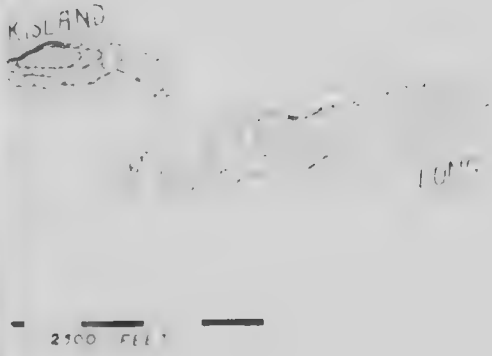
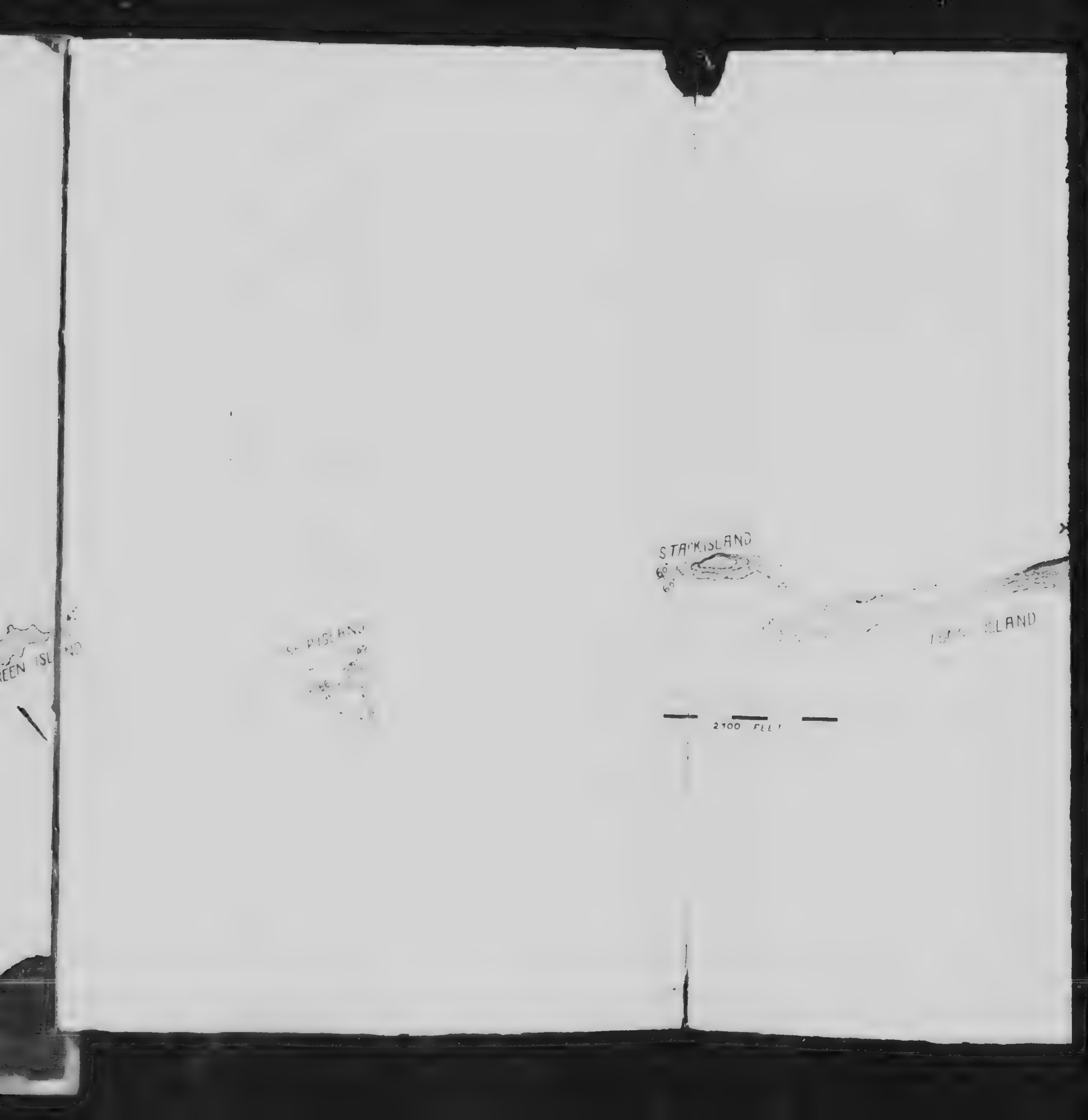
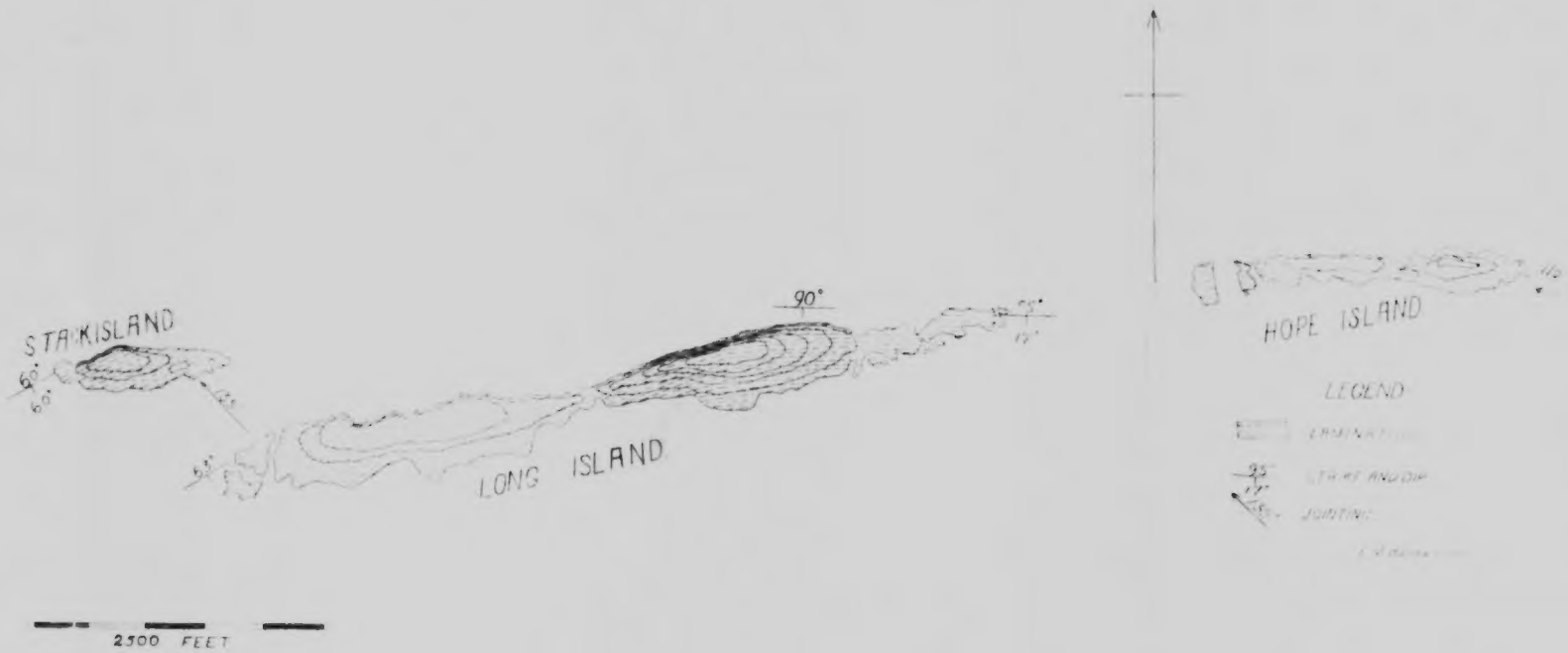

KJOLAND
2100 FEET


GREEN IS


STARK ISLAND
60°
60°
2100 FEET


GREEN ISL ND


SHIP ISLAND


STARK ISLAND
90°
LONG ISLAND
HOPE ISLAND
LEGEND
2300 FEET

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